Using Flow Modeling for Efficient Upgrades and Expansions

Adapting existing systems based on changing requirements is not simple. Engineers are required to work with outdated schematics, limited measurements, demanding requirements, and tight budgets. Although improving on existing systems is a daunting task, network modeling can help to reveal weaknesses in the system and operating equipment that may not have been apparent from system operation.

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Many projects require major changes to a processing facility beyond expected maintenance and equipment replacement; malfunctioning equipment, failure to meet demands, increased demands on the existing process, etc. Regardless of the reason, there are three key philosophies for an effective modeling process:

1. Analyze the whole system
2. Be creative
3. Think long term

Analyze the Whole System, not Just the Unit/Section in Question

In pumping systems, engineers think in terms of the network, not the single unit – every piece of equipment will have an impact on the flow and pressures at any other point in the network.

Recall that a centrifugal pump's operating point is determined by the system resistance. When a pump is sized, the appropriate pump is selected by estimating the resistance in the network and the necessary flow rate. If the system is designed well, the pump will operate close to the desired operating point upon installation. However, as the system ages, issues such as corrosion, leaks, and wear on equipment can cause the pump's operating point to shift. It is important to understand the intended system design and how the system has changed over time before making any changes to an existing system.

Design choices made for the initial system may no longer be effective based on how much the system has changed. For example, a control valve that was initially well sized for the system may now be operating close to fully open as resistance has increased elsewhere in the system, driving the overall flow rate down. Therefore, replacing that valve with the same sized valve would be ineffective. Similarly, a pump that was initially operating in its preferred operating region may now be operating at a lower flow, causing the pump efficiency to be decreased. Rather than replacing the pump or control valve, it may be possible to address the source of the increased resistance in the system to resolve these issues in the long term.

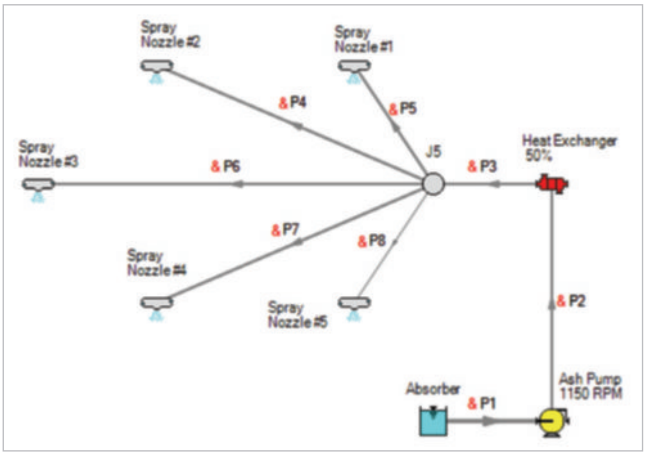

Figure 1: A circulating pump drawing caustic solution from the absorber discharges through a heat exchanger to the five spray nozzles.

To showcase the benefit of network modeling, three case studies have been provided. Each case study explores a specific issue and details how following the three key philosophies for an effective modeling process can mitigate the risk of future issues and speed up the troubleshooting process.

Case Studies

Case Study 1 – Reducing Pump Failure – Absorber System for Chemical Disposal

The case in question concerns a disposal complex for a chemical facility. The disposal process consisted of sending compounds to an incinerator, after which the broken-down compounds were absorbed into a caustic circulation system. A simplified layout of the system is shown in Figure 1. The circulation pump required excessive maintenance due to constant failure of the pump lining and bearings.

From initial analysis the main cause of the problem was the high operating speeds of the pump. Historical data was not available for the system, but a hydraulic

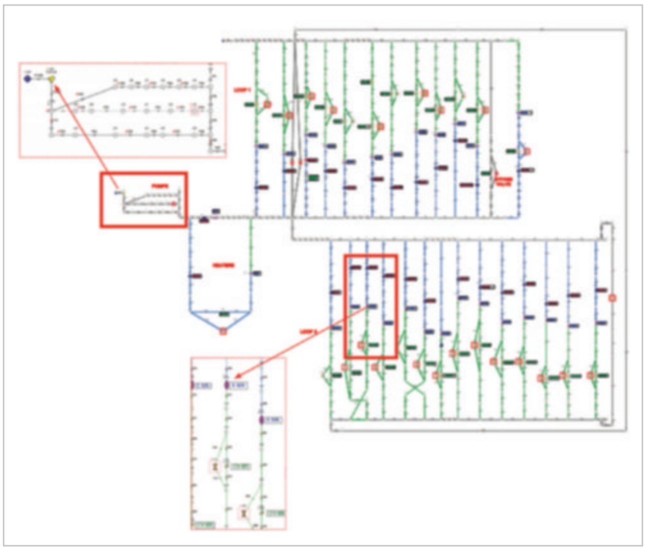

Figure 2: A diagram of the hot oil network is shown. Hot oil is pumped through the pumps to the heaters and is then delivered to twenty-six heat exchangers.

analysis was performed considering different heat exchanger fouling, liquid levels, and pump speeds to determine the current operating state of the system. A study on the pump speed was then run to determine the ideal speed for the pump required to maintain the required circulation flow rate while running the pump within its preferred operating region.

This case is an excellent illustration of considering the network as a whole. Though the problem was with the pump, care was taken to ensure that the flow could be reached by carefully considering how the pump speed would affect the operating point of the pump in the particular system.

Being Creative

Sometimes the solution to an equipment problem may be as simple as adjusting a startup procedure or the system configuration, rather than purchasing all new equipment. An issue with a major piece of equipment such as a pump or heat exchanger might be resolved by adjusting multiple minor fittings such as valves. Though an individual valve may have a low impact during normal operating circumstances, a valve that has become stuck shut will have a heavy impact.

In the physical system it is impossible to know the flow and pressure at every point in the system at any given time, thus the source of issues may not be immediately apparent to operators. This is where flow modeling can help fill in the gaps. Simulating potential causes of failure and comparing these cases to data from the system can speed up the troubleshooting process.

Case Study 2 – Increasing System Efficiency – Petrochemical Facility Hot Oil Network

For this second case, a company was hired to analyze a hot oil network to reduce the energy consumption of the system and increase efficiency long term. A hydraulic model of the system was built and verified using pressure measurements taken throughout the system, as is shown in Figure 2. Through the model, engineers analyzed the operating conditions at the pumps, hot oil heaters, and each of the heat exchanger loops that the hot oil was supplied to. Through the analysis of the equipment operating conditions, it was found that several of the flow control valves were oversized based on the large pressure drops at these points in the system.

In addition to the oversized control valves identified in the model, they found several flow elements in the heat exchanger lines could be resized to reduce their resistance in the system. Ultimately, comparison of different replacement options revealed an energy reduction of 50% could be achieved by simply replacing the oversized control valves and flow elements identified during the analysis. This also had the benefit of reducing system down time, as this involved a much less intensive installation process than replacing the main hot oil heaters or the pumps in the system.

In this case, the engineers were able to achieve an effective long-term solution by considering impacts of the individual components on the system as a whole. An innovative solution was achieved by considering the replacement of multiple smaller components, rather than focusing on replacing larger elements in the system.

Thinking Long Term

Choosing the cheapest and simplest design option may be tempting, but over the life of the system, this will not always pay off.

It is important to keep in mind that making changes to a pumping and piping system essentially results in a new system. This means analysis for worst-case scenarios should be done to ensure the "new" system still meets requirements for maximum allowable pressures, temperatures, forces, etc.

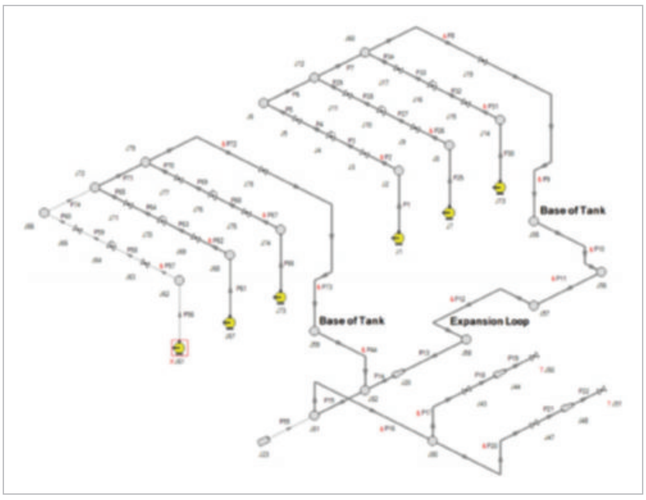

Figure 3: Liquefied natural gas facility, including the proposed system expansion.

Case Study 3 – Increasing System Capacity – LNG Facility Expansion

The last case study involved the expansion of a liquefied natural gas (LNG) plant. The owner tasked the engineering firm with increasing the send-out rate by 60% for the existing facility. During the process of adding an expansion loop to the system, care was taken by the engineers to ensure that increased capacity would not cause the maximum pressures to exceed the allowable system pressures. This included additional analysis of the potential closure of the control valves in the send-out lines to verify that surge pressures would remain within the allowable limits. The system layout can be seen in Figure 3.

Cautious design and long-term thinking allowed engineers to increase the flow in the delivery line to the condensers while limiting transient pressure surges to remain within the allowed limit.

Conclusion

Though the recommendations above may seem obvious, all of the considerations offered here are important when troubleshooting and improving pumping systems. In the current information age taking advantage of advanced tools that are available in the market today can help to reveal small details that are not obvious in day-to-day plant operations which have a big impact on productivity.

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